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ABSTRACT

Discussed are the following topics: (1) the greenhouse problem, including the processes involved and some possible resulting scenarios; (2) ozone, the "umbrella" protecting the earth from lethal concentrations of ultraviolet rays and the problem of decreasing ozone levels; (3) what could happen as the earth gets warmer (including discussions of rising sea levels, increased plant growth, and additional ultraviolet levels); (4) what can be done to minimize both greenhouse heating and ozone depletion (encouraging international cooperation); and (5) how the United Nations Environment Programme (UNEP) is helping. A bibliography is included. (TW)

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UNITED NATIONS ENVIRONMENT PROGRAMME

UNEP Environment Brief No 1

ED287681

the changing atmosphere

Chemical pollution is changing the structure of the Earth's atmosphere, threatening to alter the climate and expose human populations to higher levels of dangerous ultraviolet radiation. This publication, the first in a series of UNEP briefing documents, summarizes what is known about the two major effects involved: the build-up of greenhouse gases in the atmosphere, and damage to the ozone layer.

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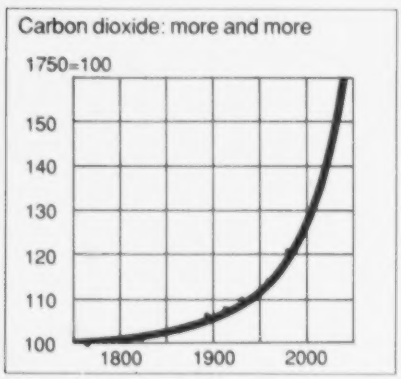
The greenhouse problem

The atmosphere that surrounds the Earth plays a critical role in maintaining even temperatures on the Earth's surface. Like the glass in a greenhouse, the atmosphere absorbs some of the long-wave radiation emitted by the Earth, and radiates energy back at the Earth. If the atmosphere were not present, temperatures on the Earth would be much lower than they are.

But industrial activity is changing the atmosphere's structure. As gases like carbon dioxide are produced and released into the atmosphere, they absorb more of the Earth's radiation, and return more of it back to the Earth. This energy, which would otherwise escape harmlessly into space, is already increasing the Earth's surface temperature, though so far



by only small amounts (about 0.5 °C over the past 120 years).

Carbon dioxide is the most important of the greenhouse gases, and is produced primarily when fossil fuels are burnt to provide power. Levels of carbon dioxide in the atmosphere have already increased by some 25 percent since the Industrial Revolution; they are expected to increase by a further 30 percent in the next 50 years.

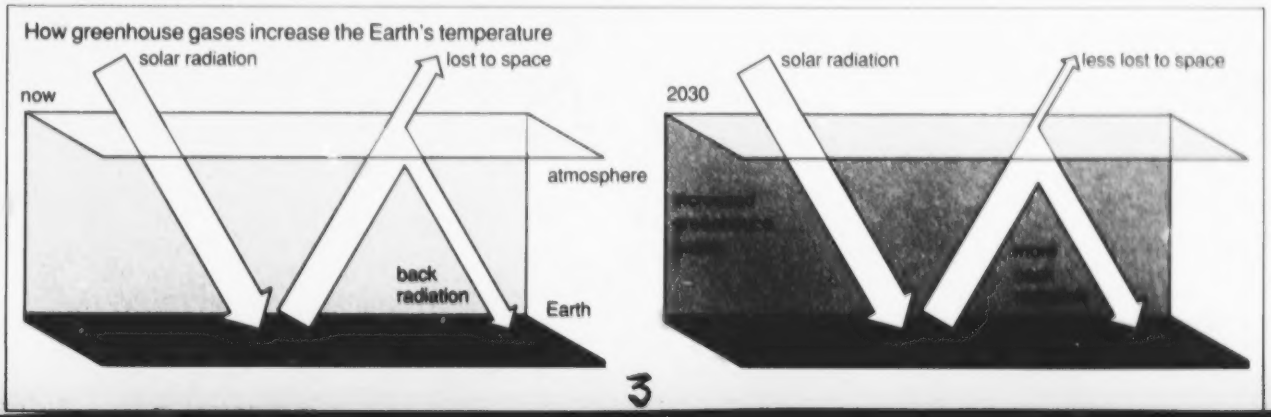
Many other gases also have a greenhouse effect. These include nitrous oxide (laughing gas), methane, ozone and chemicals used in refrigeration and other industries called chlorofluorocarbons (CFCs for short). The concentrations of these gases in the atmosphere are much lower than that of carbon dioxide but they are increasing, and many of them produce a very strong greenhouse effect. Scientists calculate that over the next half century or so the temperature rise produced by increasing concentrations of carbon dioxide will be matched by the effect of the other greenhouse gases. The carbon dioxide effect, in other words, will be doubled.

How much is the temperature likely to rise? By making assumptions about how much of each gas is likely to be released into the atmosphere, and feeding this information into computers that can model the atmosphere's behaviour, scientists can make rough estimates of what is likely to happen. Current predictions are that the greenhouse effect will amount to between 1.5 and 4.5 °C by the year 2030. Because the oceans take a long time to warm up, however, not all this increase will actually happen by 2030 – about half it will occur by then, the other half following in the ensuing decades.

Even these apparently low figures will be enough to have a major effect on climate. Temperatures averaged over the whole globe over a year disguise what can happen locally in different seasons. Though the Earth's average temperature was only about 5 °C colder than now during the last Ice Age, it was very much colder in some places in some seasons.

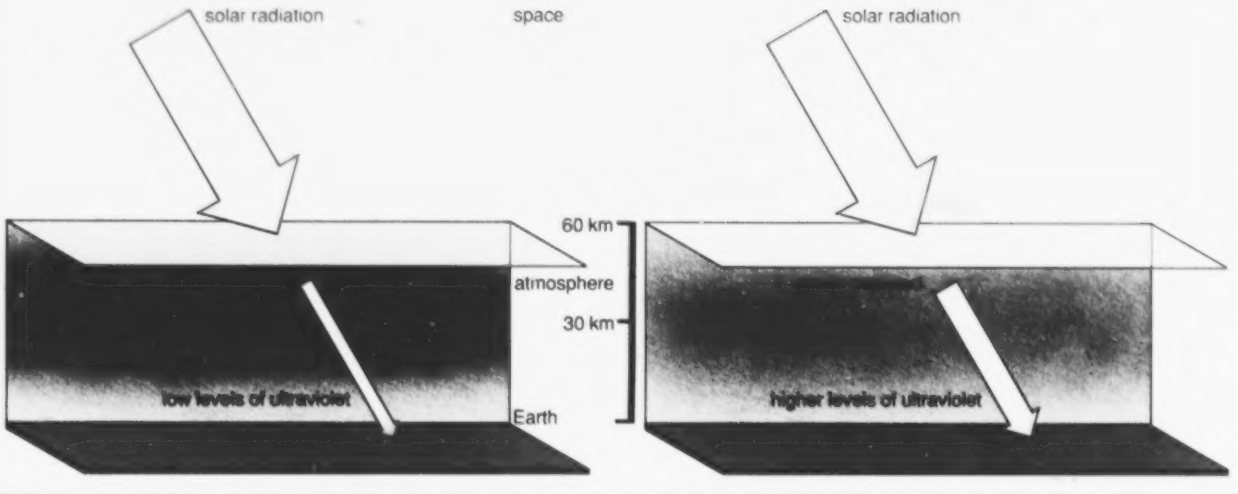
Similarly, an average temperature rise of only 3 °C could mean increases of more than 10 °C at high latitudes in some seasons. In temperate zones, winters would tend to be shorter and warmer, summers longer and hotter.

Rainfall would also be affected. Evaporation rates would increase and overall rainfall would rise by an estimated 7-11 percent a year. Temperate winters might be wetter, and summers drier. The tropics would also become wetter but the sub-tropics, already dry, could become drier still.



Ozone: the umbrella against the ultraviolet

The ozone layer: less ozone means more ultraviolet



Ozone, a gas composed of three oxygen atoms, surrounds the Earth like a delicate veil, protecting the planet and its inhabitants from the direct gaze of the Sun. Ozone is our umbrella against the ultraviolet. Were it not present in the atmosphere, lethal levels of ultraviolet radiation from the Sun would reach the Earth's surface.

Ozone is found up to heights of about 60 km. It is most dense 20-25 km up but even here only one molecule in 100 000 is ozone. If all the ozone were collected at the Earth's surface, it would form a layer only about 3 mm thick. But because there is so little of it, and because its presence is so important, small changes in ozone concentrations could have dramatic effects on life on Earth.

Ozone is produced naturally, from oxygen, high in the atmosphere. Natural forces also break it down, with the result that the gas is constantly being created and destroyed. The speeds at which these reactions occur determine how much ozone there is in the atmosphere. And these speeds can be greatly influenced by chemicals in the atmosphere which act as catalysts in the reactions, speeding them up without themselves being destroyed.

Several chemicals used in or produced by industry greatly affect the speed at which ozone is broken down. These include the chlorofluorocarbons (CFCs) which are used as the propellants in aerosols, in refrigeration technology, as foam-blowing agents in the plastics industry and as solvents in electronics. Other gases that speed up the breakdown of ozone include nitrous oxide, and those containing chlorine, fluorine and bromine.

In trying to work out what will happen to ozone levels in the future, scientists must first make predictions about how fast chemicals like the CFCs and nitrous oxide will be produced in the future. They must then make models of how these chemicals react with ozone, and with one another, and estimate future ozone levels, at different heights and at different times in the future.

The latest results of this work suggest that ozone levels will fall by a few percent during the first half of the next century– although increases in CFC emissions could cause more than a 10 percent fall in ozone. Measurements of the total amount of ozone in the atmosphere show that levels have not changed appreciably as yet – though small changes do seem to be occurring at particular heights, with low level ozone concentrations increasing, and high level ones decreasing. There have, however, been dramatic changes over the Antarctic (*see box*).

Changes of a few percent in future ozone levels would be enough to let substantially more ultraviolet radiation reach the Earth's surface. Because ozone affects the Earth's heat balance in a number of ways, climate could also be affected by changes in ozone concentrations.

Ultraviolet radiation is responsible for sunburn, snow blindness, eye damage, skin cancer, and the ageing and wrinkling of skin. It affects plant growth, slowing down photosynthesis and delaying germination in many plants, including trees and crops. Algae are particularly sensitive to ultraviolet radiation, raising fears that damage to the ozone layer could upset marine ecology and lower fish populations.

What could happen ...

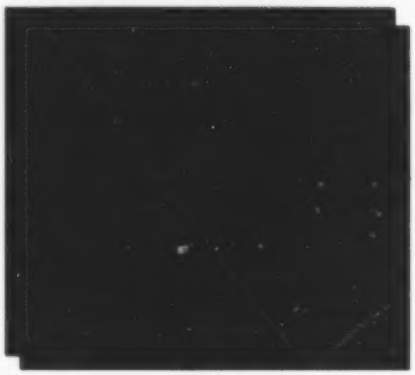
The greenhouse effect and ozone depletion are not completely separate problems. Ozone changes will affect climate, and carbon dioxide changes will influence ozone depletion. How are these changes likely to affect human society over the next half century?

Three separate effects are involved: climatic change, abnormally fast plant growth caused by high levels of carbon dioxide in the air, and increased levels of ultraviolet radiation.

Consequences of climatic change

The most obvious effect of climatic change will be on agriculture. A warmer climate is likely to move the areas suitable for growing specific crops, such as wheat, towards the poles. If soils in these areas are poorer, yields will fall. Marginal agriculture – as practised, for example, in the drought-prone Sahel – will probably suffer most because it will be unable to adapt easily to new conditions.

Changes in agriculture will, in turn, produce cascade effects throughout society, altering the economic viability of farming, agricultural employment, commodity prices, and patterns of world trade. There will also be widespread changes in natural eco-systems, with grassland and desert areas expanding, and forested areas shrinking and moving polewards. Problems such as desertification and soil erosion could worsen.



A warmer climate might make some cities unbearably hot. A wetter or drier climate would also have major effects on water use and long-term planning, perhaps making large reservoirs or other projects useless long before their normal 50-year lifetime had elapsed.

As the oceans expanded, sea levels would rise causing flooding of low-lying areas. While richer nations could afford to protect themselves – as the Dutch have done for centuries – poorer nations might have no choice but to lose large areas of precious coastal land to the sea.

Plants would grow faster and larger

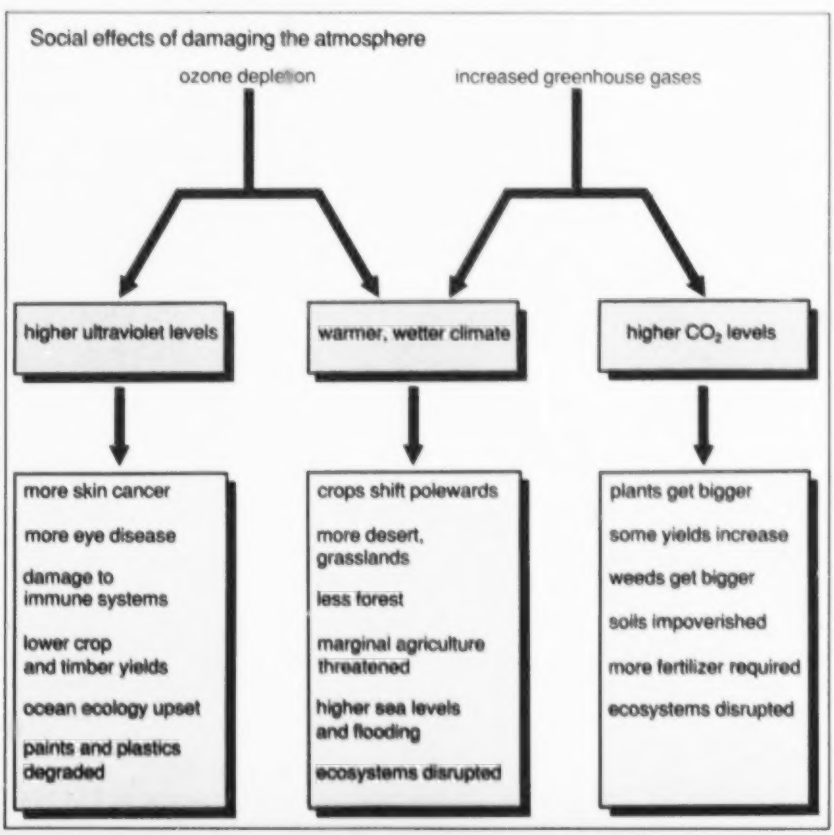
Because carbon dioxide is a natural fertilizer, most plants would grow larger and faster in a higher carbon dioxide world. At first sight, this might be thought beneficial because yields of major crops might increase. While this might be true, there would be many complicating effects: weeds would also get bigger, plants would be less rich in nitrogen and perhaps more susceptible to pests, and soils might become rapidly empoverished as a result of having to sustain high rates of plant growth.

In addition, natural eco-systems would be disrupted, with unpredictable results, as some species adapted easily to the new conditions while others dwindled or died out.

How dangerous is the ultraviolet?

Higher levels of ultraviolet radiation would have a number of major effects on society. Skin cancer - already the most common form of cancer in man - would become even more common, possibly even including the most lethal form, melanoma. Eye diseases would increase, and the ability of the body's immune system to cope with infections might be impaired. The yields of many crops could fall because ultraviolet radiation slows down many aspects of plant growth.

Plastics are also affected by ultraviolet radiation, and the lifetimes of many commonly used synthetic materials could be shortened. They might have to be renewed more frequently than in the past, at great economic cost. In addition, ozone depletion is likely to lead to more smog in cities.

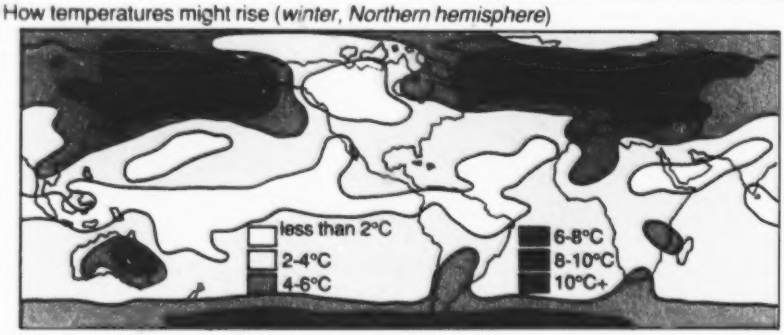


... as the Earth gets warmer

The Earth's climate has not varied by more than 1 or 2 °C in the past 10,000 years. The warming expected in the next 50 years will thus exceed any climatic change experienced in human history.

Models of the Earth's climatic system are not yet sufficiently reliable to predict exactly how a given change in average temperature will affect the different regions of the Earth. But, as the map on the right shows, they do give an indication of what might happen, with large temperature changes occurring in the high latitudes, particularly in the the world's major grain growing areas.

How temperatures might rise (*winter, Northern hemisphere*)



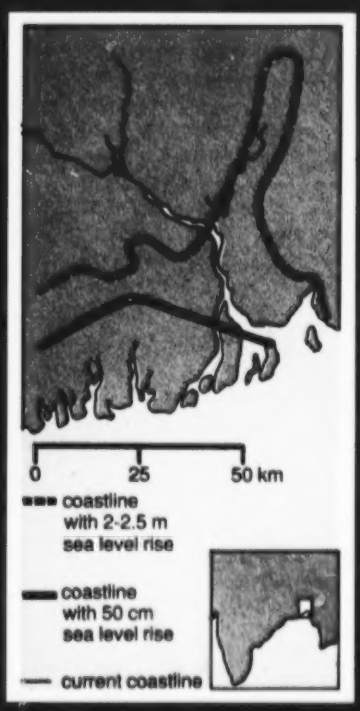
While warmer temperatures speed crop growth, they do not necessarily lead to higher yields: muggy conditions, for example, provide ideal breeding grounds for pests and diseases. Because agriculture is generally well adapted to existing climatic conditions, any major change is likely to prove disruptive rather than beneficial. This would be particularly true where crops are farmed on marginal land.

One climatic model suggests that greenhouse warming could cause a temperature increase of 3.4 °C and an increase in rainfall of 18 percent in some parts of Canada. This would lower wheat production by 25 percent, resulting in a fall in employment and gross domestic product.

Natural eco-systems would also be disrupted, with grasslands and deserts expanding in area, and forested areas growing smaller. The mix of plants in rangelands would alter, with unknown consequences for the stock grazing them.

Climatic change might also exacerbate existing problems such as desertification, drought and soil erosion. Ecological hazards such as floods, storms and forest fires might become more common, and warmer winters could enable more pests to survive winters in which they would previously have perished.

The world water cycle is likely to be profoundly influenced by the greenhouse warming, with rainfall increasing in many areas but with soils becoming drier as evaporation rates increase. All this would have a major effect on surface water run-off, and many dams, reservoirs and hydro-electric schemes might become useless. Planning would become impossibly difficult if the climate began to change fast.



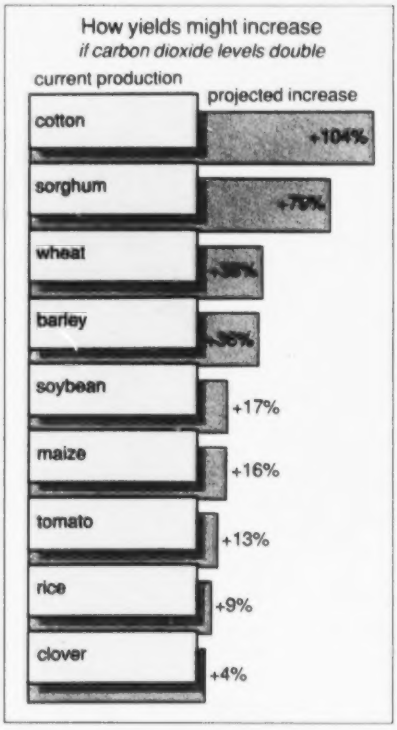
... plants get bigger

Because carbon dioxide is a natural fertilizer, plants will grow faster and larger in a higher carbon dioxide world. If carbon dioxide levels double– as they may do by later in the next century– the yields of many crops, and weeds, could increase by an average of about a third.

Plants have widely differing responses to increased carbon dioxide so it is difficult to predict what effects this could have on agriculture. Yields of some crops could even double while those of others changed very little.

Response depends on how a plant photosynthesizes. Plants that produce intermediary chemicals with three carbon atoms, the C_3 plants, respond well; those that produce intermediaries with four carbon atoms, the C_4 plants, much less so.

Of the world's 20 major food crops, 16 are C_3 plants. The other four– maize, sorghum, millet and sugarcane– are C_4 plants, whose yields would not be expected to increase greatly. Unfortunately, three of these are the staple foods of most of sub-Saharan Africa, where food is already in short supply.



While increased yields would be beneficial in many areas, this would not be true in the United States, the EEC countries and Japan; here over-production is already agriculture's principal problem. Further yield increases would lower prices and subject farmers to increasing economic pressure.

Bigger plants with larger yields could raise other problems, too. Unless larger amounts of expensive fertilizer were used, the soil might well become impoverished as it struggled to provide the nutrients required by an increased crop cover.

... and the ultraviolet increases

If ozone levels are depleted by a few percent early in the next century, there will be increased levels of a portion of the spectrum known as UV-B on the Earth's surface. UV-B causes skin cancer and eye disease in man, slows down plant growth, is lethal to marine algae and breaks down the chemical structure of paints and plastics.

Currently, between 10 and 30 percent of the Sun's UV-B reaches the Earth's surface. If ozone levels were to fall by 10 percent, the amount of UV-B reaching the Earth would increase by about 20 percent.

Worldwide, about 100,000 people die from skin cancer every year – and UV-B is implicated in most cases of skin cancer. In the United States, the National Academy of Sciences has estimated that each 1 percent depletion of ozone would increase the incidence of skin cancer by 2 percent. On this basis, a 3 percent reduction in ozone would produce some 20,000 more cases of skin cancer in the United States every year.

Other medical effects are harder to quantify: more UV-B will increase eye disease, skin ageing and wrinkling, and probably impair the body's ability to cope with infections in general.

Some 200 species of plants have been tested for sensitivity to UV-B, and about two-thirds of them respond – growth is slower and pollen may fail to germinate. A 25 percent ozone depletion, for example, would be expected to lower soybean yields by 20-25 percent. It is thought that trees and grasses would be particularly badly affected by higher UV-B levels.

Fish, and the algae on which they feed, may also fare badly. Recent research shows that a 15-day exposure to UV-B levels 20 percent higher than normal can kill off all anchovy larvae down to a water depth of 10 metres. More UV-B is likely to lower fish catches and upset marine ecology. Worldwide, fish currently provide 18 percent of all the animal protein consumed.

Even today's levels of sunlight provide enough UV-B to cause substantial economic damage. It is UV-B that causes paints to fade, window glazing to yellow, and car roofs to become chalky. These kinds of degradation will accelerate if the ozone layer is depleted.

Finally, more UV-B will mean more smog – an effect that will be accentuated if temperatures rise as a result of greenhouse warming. Urban air pollution caused by UV-B could also worsen the problem of acid rain in cities.

What can be done?

International action is urgently required to minimize both future greenhouse heating and ozone depletion. Because it takes decades for human actions to produce any effect on the structure of the atmosphere, a start has to be made now. While something has already been done to control ozone depletion, little effort has gone into tackling the greenhouse problem which is, in many ways, the more serious issue.

Sorting out the greenhouse problem

There are four possible solutions to the greenhouse problem:

- reduce the rate at which fossil fuels are burnt and other greenhouse gases produced;
- dispose of the greenhouse gases as they are produced elsewhere than in the atmosphere;
- recover the greenhouse gases already in the atmosphere and dispose of them elsewhere; and
- accept the changing climate and adapt to it.

Only the first and last solutions appear economically feasible. Carbon dioxide, for example, could be filtered from power station effluents, converted to some other chemical form, and dumped on the ocean floor. But the cost would be enormous.

Carbon dioxide which is already in the atmosphere could, in theory, be 'mopped up' by planting more trees on the Earth which would convert carbon dioxide in the atmosphere into woody tissue. But an area the size of France would have to be planted annually to compensate for the current rate at which carbon dioxide is produced. Even if this were possible, the effects of the other greenhouse gases would still change future climates.

The most promising ways forward are to reduce overall energy consumption – something that is already happening, thanks to the increased oil prices of the 1970s – consume less fossil fuels by relying increasingly on nuclear and solar energy, for example, and learn to adapt and accept the changing climate. Future actions are likely to include a combination of these three approaches but international mechanisms to formulate an agreed plan have yet to be put into effect.

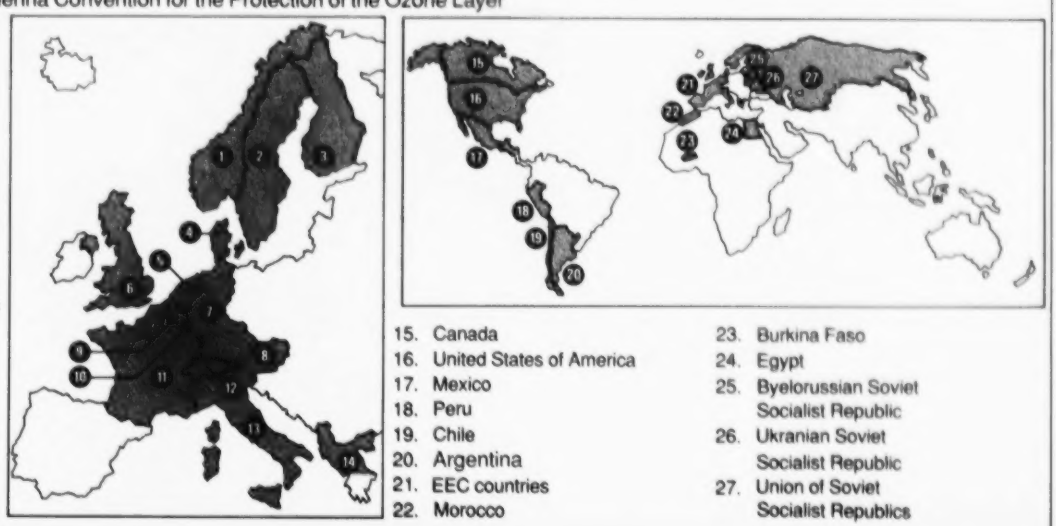
Protecting the ozone layer

Action has already been taken to protect the ozone layer. Because the major danger comes from the chemicals called chlorofluorocarbons (CFCs), and because these were widely used as the propellants in aerosols, several countries have restricted the use made of CFCs or the amounts produced. The United States banned the use of CFCs in aerosols in 1978. The EEC has introduced its own regulations and some countries, such as Belgium and the Nordic countries, have in effect banned CFC production altogether.

Furthermore, a Convention for the Protection of the Ozone Layer was adopted in Vienna in March 1985 by 21 states and the EEC. Though the Convention is not yet in force, it has since been signed by more states (*see map below*). The Convention pledges parties to it to protect human health and the environment from the effects of ozone depletion; two annexes to the Convention provide for parties to it to cooperate in research, observation and information exchange on matters connected with ozone depletion.

A Protocol to the Convention is currently being framed that will pledge signatories to limit their production or emissions of CFCs.

Signatories to the Vienna Convention for the Protection of the Ozone Layer



1. Norway
2. Sweden
3. Finland
4. Denmark
5. Holland
6. United Kingdom of Great Britain and
7. Northern Ireland Federal Republic of Germany
8. Austria
9. Belgium
10. Luxembourg
11. France
12. Switzerland
13. Italy
14. Greece
15. Canada
16. United States of America
17. Mexico
18. Peru
19. Chile
20. Argentina
21. EEC countries
22. Morocco
23. Burkina Faso
24. Egypt
25. Byelorussian Soviet Socialist Republic
26. Ukranian Soviet Socialist Republic
27. Union of Soviet Socialist Republics

How UNEP is helping

Concern with the ozone layer was one of the environmental issues that led to the creation of the United Nations Environment Programme in the early 1970s.

UNEP is working with governments, international organizations, and industry to develop a framework within which the international community can make decisions to minimize atmospheric changes and the effects they could have on the Earth. In 1977 UNEP convened a meeting of experts to draft the World Plan of Action on the Ozone Layer. The Plan called for a programme of research on the ozone layer and on what would happen if the layer was damaged. To coordinate this programme UNEP created a special body, the Coordinating Committee on the Ozone Layer (CCOL).

By 1986, the CCOL had met eight times, and had assessed the threat to the ozone layer on several of them – the most recent being in 1986.

UNEP also created the group of experts and government representatives that framed the Convention for the Protection of the Ozone Layer, and is working with governments on a Protocol to the Convention that will require signatories to it to limit their production or emissions of CFCs. This raises

difficult commercial issues because CFCs are important industrial chemicals.

UNEP also took action to tackle the greenhouse problem early in the 1970s when the organization joined forces with the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) to place study of the greenhouse effect on a firm scientific footing.

The results of that initiative have been a much clearer understanding of the nature of the greenhouse effect, and its implications for the future. Thanks to the urgent studies made during the late 1970s and early 1980s, much of the guesswork about both ozone depletion and the greenhouse effect have been removed. The reality of both issues is no longer at issue; the only questions remaining are when, and how much.

Work in coordinating international legal action about the greenhouse effect has so far not been begun except in relation to the CFCs– partly because the issues are more complex and the solutions less obvious. However, UNEP is working with governments, WMO, ICSU and other international bodies to develop a better understanding of the greenhouse effect. This is planned to lead to a framework within which the community of nations will be able to make informed decisions on how best to minimize greenhouse heating and its social effects.

To learn more ...

More detailed accounts of the issues discussed in this publication can be found in:

International Council of Scientific Unions, United Nations Environment Programme and World Meteorological Organization. *Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of other Greenhouse Gases in Climate Variations and Associated Impacts*, Villach, Austria, 9-15 October 1985. Geneva, WMO, 1986.

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UNEP: PO Box 30552, Nairobi, Kenya
(phone Nairobi 333930, telex 22068)

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